Management of Malunions, Nonunions, and Late Syndesmotic Injuries of the Ankle

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1 Etiology and Pathomechanics

Although commonly seen in orthopaedic practice, ankle fractures are often complex and underestimated during primary treatment, leading to poor outcomes due to inadequate reduction or fixation with secondary loss of reduction [1–4]. Malunion and/or nonunion then occurs affecting the articular congruency and anatomical axis of the joint. This leads to asymmetrical loading and abnormally high load stresses on the articular contact surfaces [5–9]. The alteration in load distribution, often with talar subluxation, can progress to posttraumatic ankle osteoarthritis [8, 9]. In addition, intra-articular malunion of the tibial plafond can also occur due to residual step-offs on the articular surface of the distal tibia from improperly reduced pilon fractures or neglected partial impactions of the tibial plafond in malleolar fractures [6, 7].

Posttraumatic deformities of the ankle are not uncommon with reported malreduction rates of up to 44% following operative treatment [10–12].

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Besides bony deformities, chronic ligamentous instabilities are frequent findings that may occur in isolation or in combination with bony malunion [4, 12]. On the contrary, malleolar nonunions are only seen rarely with the advancement in stabilization of displaced malleolar fractures [4, 5].

A deviation of ≥10° from the anatomical axis leads to significantly decreased tibiotalar contact area [13, 14]. Lateral translation of the talus by 1 mm decreases the articular contact surface by 42% in a static biomechanical model [8]. In other clinical and biomechanical studies, fibular shortening or translation of ≥2 mm was associated with eccentric load shift in the ankle joint and inferior outcome [9, 10, 12]. This alteration is reversible with a corrective osteotomy of the fibula [15]. Besides, intra-articular step-off of ≥2 mm in posterior malleolar malunion has also been shown to be an independent risk factor for inferior outcomes and development of posttraumatic arthritis irrespective of the fragment size [16]. The impact of fibular malrotation is less clear. Although a fibular rotation of 5° can result in significant weight shift at the ankle joint in a biomechanical setting, the patients in a clinical study did still tolerate up to 15° of fibular rotation [9, 10]. Besides inadequate assessment and treatment at initial presentation, patient-related factors leading to malunions and nonunions such as noncompliance, smoking, substance abuse, and comorbidities like diabetes mellitus or osteoporosis have to be considered.

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Numerous studies have demonstrated poorer clinical outcome following malreduced ankle fractures when compared to patients with anatomically reduced fractures at the time of initial surgery [10, 12, 16–18]. Similarly, inaccurate articular reduction of the tibial plafond has also been shown to be negative prognostic factor [6, 11]. Reasons include overlooked marginal plafond impaction in malleolar fractures or definite treatment of AO/OTA type C pilon fractures with external fixation, leading to improper joint reduction which is reported in up to 25% [11, 16]. Finally, malreduction of the distal fibula into the tibial incisura (notch) following syndesmotic injury has been identified as an independent negative prognostic factor in several studies [10, 12, 19, 20]. This can occur in isolation or in combination with bony deformities and will be addressed in section 5 of this chapter.

2 Preoperative Planning

A complete assessment of the patient with residual complaints after ankle fractures is vital to achieve a successful outcome. Clinical examination includes gross deformities, callosities, swelling, soft tissue condition including previous surgical scars, ulcers and skin defects, neurovascular status, residual range of motion, and joint stability. The uninjured leg should always be evaluated, too, because it serves as a reference for the patient's physiological status. Comorbidities such as diabetes mellitus, peripheral vascular disease, osteoporosis, rheumatoid arthritis, neuropathy, and risk factors such as smoking or substance abuse must be noted. The patient's primary complaint and functional deficits in terms of impairment of activities of daily living, work, and sports should be ascertained. Ambulatory status, walking aids, orthotics, and regularly worn shoes are reviewed preoperatively. The patient must be counselled about possible complications and the chance of residual deformity that cannot be corrected due to soft tissue contracture and scarring as well as functional deficits due to swelling, stiffness, and pain.

It is important to obtain bilateral weight-bearing anteroposterior and lateral radiographs of the foot and ankle prior to any corrective surgery [4]. In addition, a special projection showing the hindfoot alignment with respect to the tibial axis with the patient standing is important to distinguish the true level of deformity at the hindfoot and compensatory deformities. These special views are commonly referred to as hindfoot alignment view or long axial view [21]. If the clinical examination raises the suspicion of an additional deformity at the knee or a limb length discrepancy, standing long leg alignment radiographs should be taken from the hip to the heel.

Computerized tomography (CT) imaging is very useful in demonstrating the three-dimensional (3D) outline of complex malunions, extent of bone loss and nonunion, avascular necrosis, subchondral cysts, and severity of arthritis of both the ankle and adjacent joints. The use of weight-bearing CT imaging improves the visualization of the ankle and hindfoot alignment under physiologic loading. This is helpful if additional or compensatory deformities at the hindfoot are suspected in the presence of ankle deformities [4, 22]. A 3D printed reconstruction of the deformity can also be produced to help aid preoperative planning for complex deformities in terms of planning the level of osteotomy and optimal implant placement [22]. However, these resources may not be widely available at present and can be costly. Magnetic resonance imaging (MRI) is often used for evaluation of osteochondral defects, ligamentous, and tendon injuries as well as determining the presence and extent of AVN within the tibial plafond or talus. Nonetheless, it is in the authors' experience that MRIs produce many false-positive pathologic diagnoses in the foot and ankle and tend to over-read AVN and cartilage damage [4]. Cartilage mapping with T2 weighted MRI may provide a more sensitive information about cartilage quality [23].

At the time of surgery, it is important to assess the status of the joint cartilage visually and mechanically by probing the cartilage over the tibial plafond and talus [4]. This is because the primary cartilage damage at the time of trauma and the secondary damage from eccentric loading due to malalignment and/or instability will almost always lead to radiographic evidence of posttraumatic arthritis. Therefore, examination of the cartilage status during reconstructive surgery will in many instances provide the definitive decision to preserve or fuse/replace the ankle joint. If the joint surface cartilage is of good quality and has reasonably good covering on more than 50% of the joint surface, a joint preserving reconstruction may still be possible [1, 2, 4, 6, 14, 24]. This aspect of the surgery should be discussed with the patient preoperatively.

3 Indications for Joint-Preserving Procedures

Joint preserving osteotomies to manage intra- and/or extra-articular deformities of the ankle are usually indicated in the following cases [1, 2, 4–7, 13, 14, 24]:

1. Young, active patients.
2. Good bone stock.
3. Sufficient cartilage coverage over the weight bearing areas (first to second degree chondromalacia and at more than 50% of the ankle joint articular surface should be preserved in asymmetric ankle arthritis more commonly in the coronal plane and less so in the sagittal plane).
4. Compliant patient.

Conversely, contraindications to joint preserving osteotomies include:

1. Poor bone stock with extensive AVN of the tibial plafond or talus.
2. Loss of cartilage at 50% or more of the ankle joint surface.
3. Poor soft tissue coverage from initial trauma/open fracture.
4. Chronic bone infection (osteomyelitis).
5. Poor patient compliance (smoking, substance abuse, severe mental impairment).
6. Comorbidities such as recalcitrant, poorly controlled diabetes mellitus, severe peripheral vascular disease not amenable to revascularization or systemic disorders that can cause threat to life such as those with ASA $\geq$ 3.

In patients contraindicated for ankle joint preserving osteotomies, ankle arthrodesis is an acceptable alternative as it is a definitive surgery that will correct deformity, reduce pain, and improve function [25]. Ankle arthroplasty is also a good alternative for those patients with good functional ankle range of motion without significant AVN or bone loss of the tibial plafond [4]. These alternative treatment options will be discussed in detail in other chapters.

If joint-preserving reconstruction is pursued, the prospect of progressive arthritis despite deformity correction and realignment of the weight-bearing forces should be discussed at length with the patient. On the other hand, with joint-preserving procedures, no bridges are burnt, and if ankle fusion or replacement become necessary at a later stage, it can be performed on a well-aligned ankle, which is technically less demanding and less prone to complications. Finally, any late consequences of ankle arthrodesis or ankle arthroplasty like adjacent joint arthritis and loosening of the prosthesis are further delayed into the future, thus "buying time" for the predominately young patient with posttraumatic ankle arthritis.

4 Malunions and Nonunions of the Ankle

4.1 Types of Deformities and Reconstructive Options

Pathoanatomy of malleolar malunion usually follows the initial mechanism of injury with its resultant bony and ligamentous lesions. When considering reconstructive options, the surgical approaches can be guided according to the location of the malpositioned malleoli. Acute ankle fractures (AO/OTA 44) are classified as unimalleolar, bimalleolar, trimalleolar, and quadrimalleolar fractures [3, 26], Thus, **malleolar malunions and nonunions** (Fig. 1) can be divided in posttraumatic deformities of the:

1. Lateral malleolus.
2. Medial malleolus.
3. Posterior malleolus.
4. Anterior malleolus.

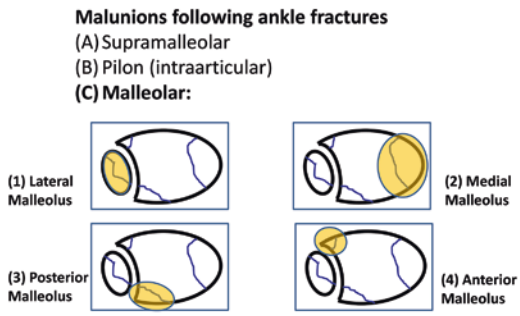

Fig. 1 Ankle malunions may be easily characterized like acute ankle fractures with respect to the affected malleoli. Malunions of the tibial pilon (supramalleolar and intra-articular) and talus are of distinct etiologies

As with acute malleolar fractures, all **combinations** of bony injuries can be observed and may be further combined with **ligamentous instability** (most frequently syndesmotic and medial instability which will be dealt with in detail in the last part of this chapter), and **partial impactions of the tibial plafond**.

Malunions following tibial **pilon fractures** can be supramalleolar or intra-articular [7] depending on the initial type of injury (AO/OTA 43A vs. B or C). The latter are rarely amenable to joint-preserving corrections due to the amount of initial cartilage damage from axial impaction and the typically rapid progression to symptomatic osteoarthritis [6, 11]. Finally, **malunions and nonunions of the talus** [4] will in many cases also affect ankle joint but are beyond the scope of this chapter.

4.2 Lateral Malleolar Malunion

The typical pathoanatomy of the lateral malleolar malunion (Fig. 2) illustrates an inadequately treated ankle fracture with fibular shortening that is often accompanied by external rotation, lateral

Fig. 2 Radiographic landmarks for fibular reduction and correction (Weber indices [1]). (1) Trilateral intervals of the ankle joint should be equal and parallel, the medial clear space should not be wider than the superior clear space. (2) The medial spike of the fibula ("*Weber-Nase*", German for "Weber's nose") should indicate and continue the level of the tibial subchondral bone ("Menard-Shenton line of the ankle"). (3) The contour of the lateral talar process continues as an unbroken curve to the peroneal recess in the distal fibula ("*Weber–Kreis*", German for "Weber circle" or "dime sign"). [From: Rammelt S, Zwipp H. *Korrektur fehlverheilter Fibulafrakturen.* In: Hamel, J, Zwipp H (eds.): Meistertechniken in der operativen Orthopädie und Unfallchirurgie. Sprunggelenk und Rückfuß. Berlin, Springer, 2016, S. 83–92, with permission]

and posterior displacement of the distal fragment [1]. This results in increased lateral tibiatalar contact forces [27]. In the presence of a medial malleolar malunion, nonunion, or deltoid ligament instability (Fig. 3), the talus will rotate externally and shift laterally following the displaced fibula [1, 4, 28]. This will decrease the superior tibiotalar contact [8, 27]. In addition, the medial malleolus may be malunited following a bimalleolar fracture where the deltoid ligament is intact pulling the medial malleolar fragment laterally as well [1, 4, 28]. Occasionally, an additional malunited posterior malleolus and/or the anterolateral tibial tubercle (anterior malleolus/ Chaput fragment) can be present as well [30]. Because both are attached to the tibiofibular syndesmosis, this may manifest as syndesmotic instability with widening of the mortise and tibiofibular clear space due to bony displacement and malunion [29, 30].

The treatment of choice is a fibular osteotomy (Fig. 4) which is primarily aimed at lengthening the shortened fibula while correcting any accompanying valgus or rotational deformity [1]. This technique uses a lateral approach to the fibula while protecting the superficial peroneal nerve especially at the proximal portion of the incision. An oblique or Z-shaped fibular osteotomy (see Fig. 16) is sufficient for lengthening up to 5 mm without the need for bone grafting [7, 28]. However, if further lengthening is required, a transverse osteotomy with corticocancellous bone graft from the tibia or iliac crest would be more reliable [1]. Once the osteotomy is completed, a rigid straight plate is first fixed to the distal fragment of the fibula. A single cortical

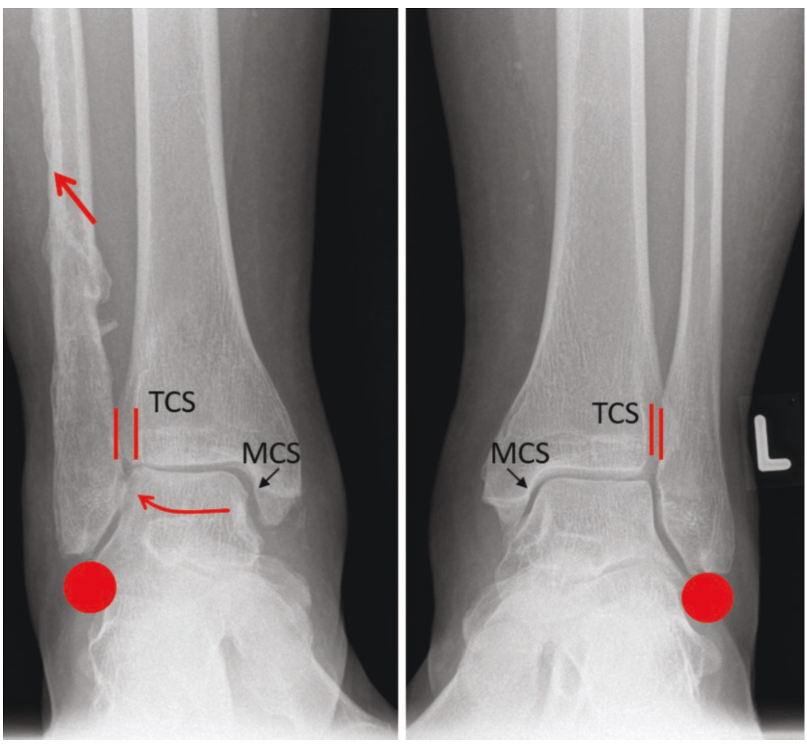

Fig. 3 Bilateral standing radiographs (mortise view) of a patient with painful fibular malunion. Note the mismatch of the Weber circle, widening of the tibiofibular clear space (TCS) and medial clear space (MCS) when compared to the superior clear space and to the uninjured side. The former oblique line of the high fibular fracture with shortening can still be delineated (red arrow). Frequently, as in this case, the fibular spike cannot be clearly seen in malunions. [Adapted from: Rammelt S, Zwipp H. *Korrektur fehlverheilter Fibulafrakturen.* In: Hamel, J, Zwipp H (eds.): Meistertechniken in der operativen Orthopädie und Unfallchirurgie. Sprunggelenk und Rückfuß. Berlin, Springer, 2016, S. 83–92, with permission]

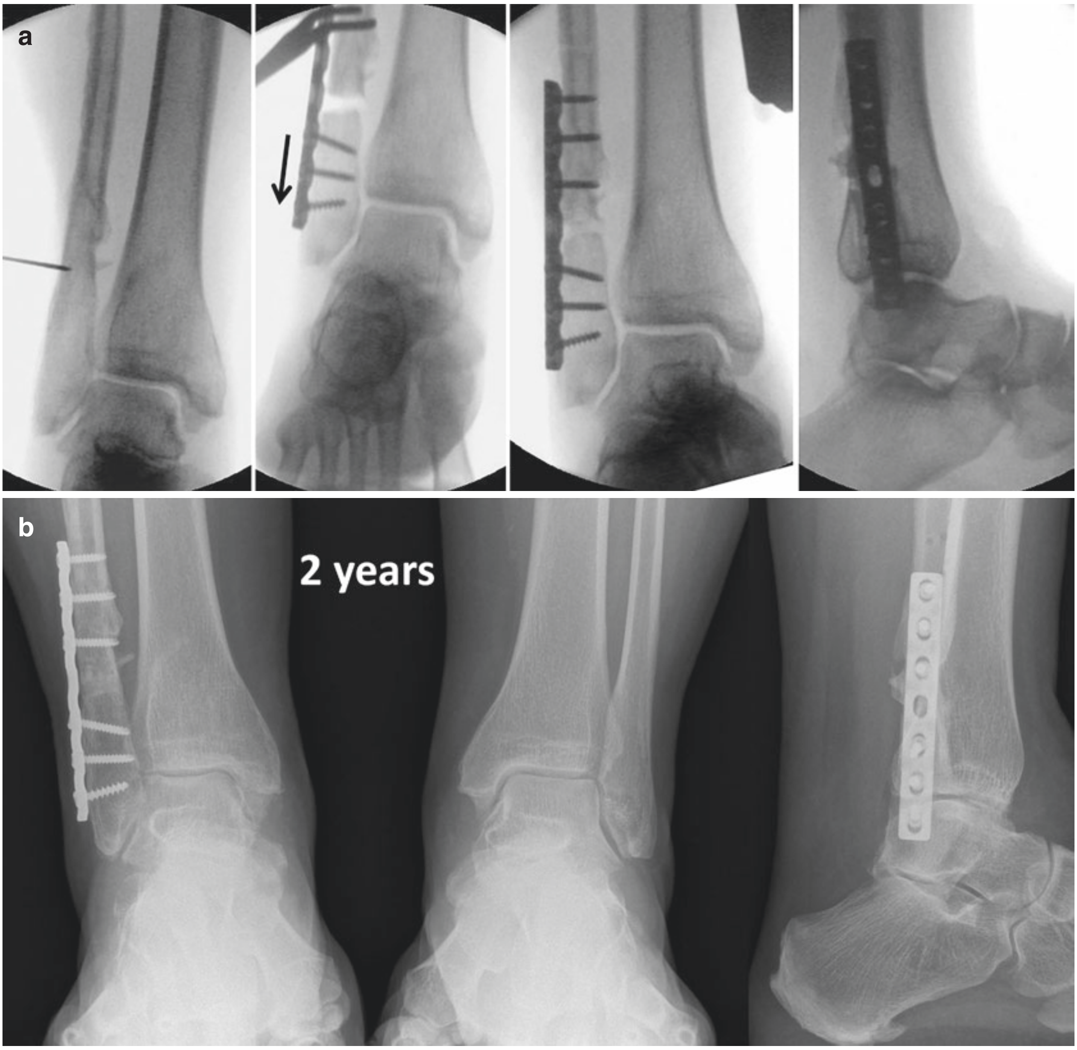

Fig. 4 Classical technique of fibular lengthening (same patient as in Fig. 3). (**a**) The horizontal osteotomy is marked with a K-wire and the plate fixed in the distal fragment. With a laminar spreader introduced between the proximal end of the plate and a separately placed screw, the correct fibular length can be fine-tuned under fluoroscopy. Then the plate is fixed proximally and the gap is filled with a bicortical bone graft from the iliac crest. Note the correction of the Weber indices. With fibular lengthening, the syndesmotic fibres are stretched and the TCS is normalized so that no separate syndesmotic stabilization is needed. (**b**) At 2 years follow-up the patient has a congruent and stable mortise without functional restrictions. [Adapted from: Rammelt S, Zwipp H. *Korrektur fehlverheilter Fibulafrakturen.* In: Hamel, J, Zwipp H (eds.): Meistertechniken in der operativen Orthopädie und Unfallchirurgie. Sprunggelenk und Rückfuß. Berlin, Springer, 2016, S. 83–92, with permission]

screw is inserted proximal to the plate and with the use of a lamina spreader or plate tensioner, the distal fragment of the fibula is lengthened accordingly. Image-intensifier can be used here to ascertain congruency of the ankle mortise after lengthening using the Weber indices [1]. Once the desired length is achieved and deformity has been corrected, the plate is fixed proximally. Mild residual valgus will be corrected once the rigid straight plate is tightened as the straightened fibula would push the talus medially. The accompanying rotational deformity of the distal fibular fragment will correct as it glides distally along the curved lateral facet of the talus through lengthening of the fibula with the foot in neutral position [7]. Alternatively, rotational correction can be controlled using K-wires introduced into the distal and proximal fragments at the exact angle of malrotation as measured with the preoperative CT scan. These K-wires should be parallel after completion of reconstruction [7]. Using the K-wire method in a cadaver study, experimental fibular malrotation could be restored within 1.6° of the values of the uninjured side as judged with CT scanning [31].

In the event of an additional medial malleolus malunion, the correction via fibula osteotomy should only be attempted once medial malleolar malunion has been osteotomized and freed from intervening scar tissues. Even if there is no medial malleolar malunion, the medial clear space has to be debrided to remove scar tissues if it does not close with fibular correction. Any remaining deltoid ligament instability as evident from residual valgus tilt of the talus in the ankle mortise, can be reconstructed simultaneously once the fibular lengthening is completed.

In case of **fibular nonunion**, the fibrous pseudarthrosis and any sclerotic bone is removed until viable bone becomes visible at both ends. Typically, nonunions will be accompanied by malposition of the fragments necessitating correction as outlined above [5, 6]. The resulting gap is filled with bone graft and fixation is typically achieved with a plate (Fig. 5). Adjunct treatments like bone morphogenic protein or bone stimulation should be considered. Any underlying comorbidities potentially leading to nonunion must be addressed. In particular, blood glucose levels should be controlled tightly and smoking strongly discouraged. Blood supply to the foot and ankle should be optimized preoperatively in case of peripheral vascular disease [5]. The few available studies on fibular nonunions uniformly report favourable mid-term results with this treatment regimen [5, 7, 32].

Multiple authors have shown good results and outcomes from fibular lengthening as treatment of malunited ankle fractures [1, 2, 4, 6, 7, 24, 28]. Reidsma et al. reported good or excellent results obtained in 85% of patients lasting up to 27 years with secondary ankle fusion in less than 15% of

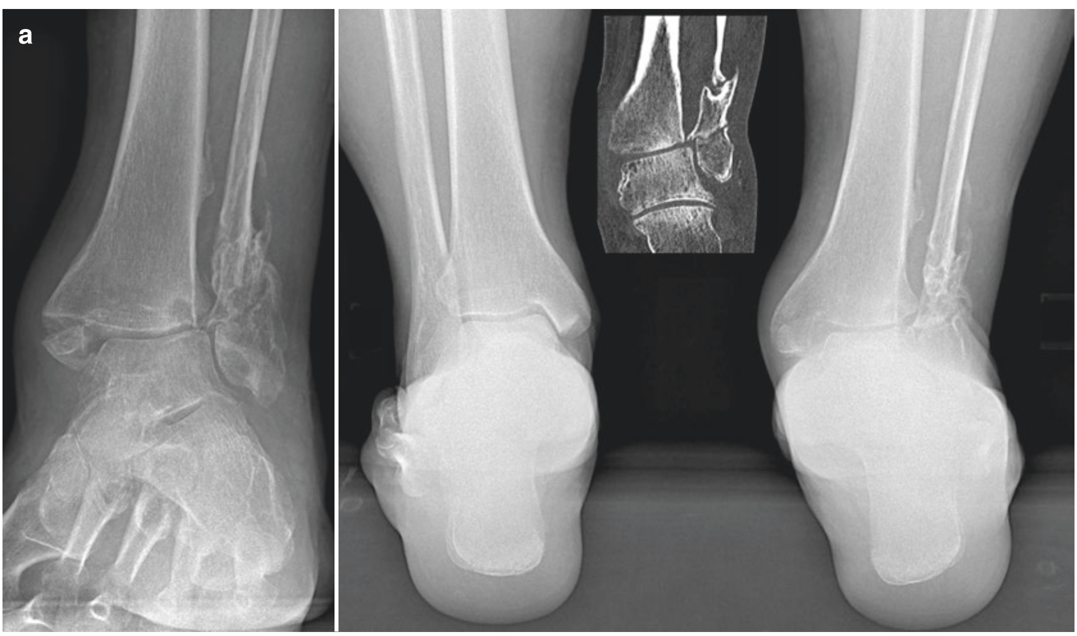

Fig. 5 (**a**) Anteroposterior radiographs, hindfoot alignment views and CT image of a nonunion of the distal tibia and fibula following a bimalleolar fracture. The ankle and hindfoot are in valgus because of fibular shortening and lateral shift of the talus. (**b**) Intraoperative aspect of the two-level nonunion of the distal fibula. (**c**) Treatment consisted of debridement of the fibrous pseudarthrosis, bone grafting, correction of the malposition and internal fixation. All former nonunions were solidly healed at 10 weeks post correction

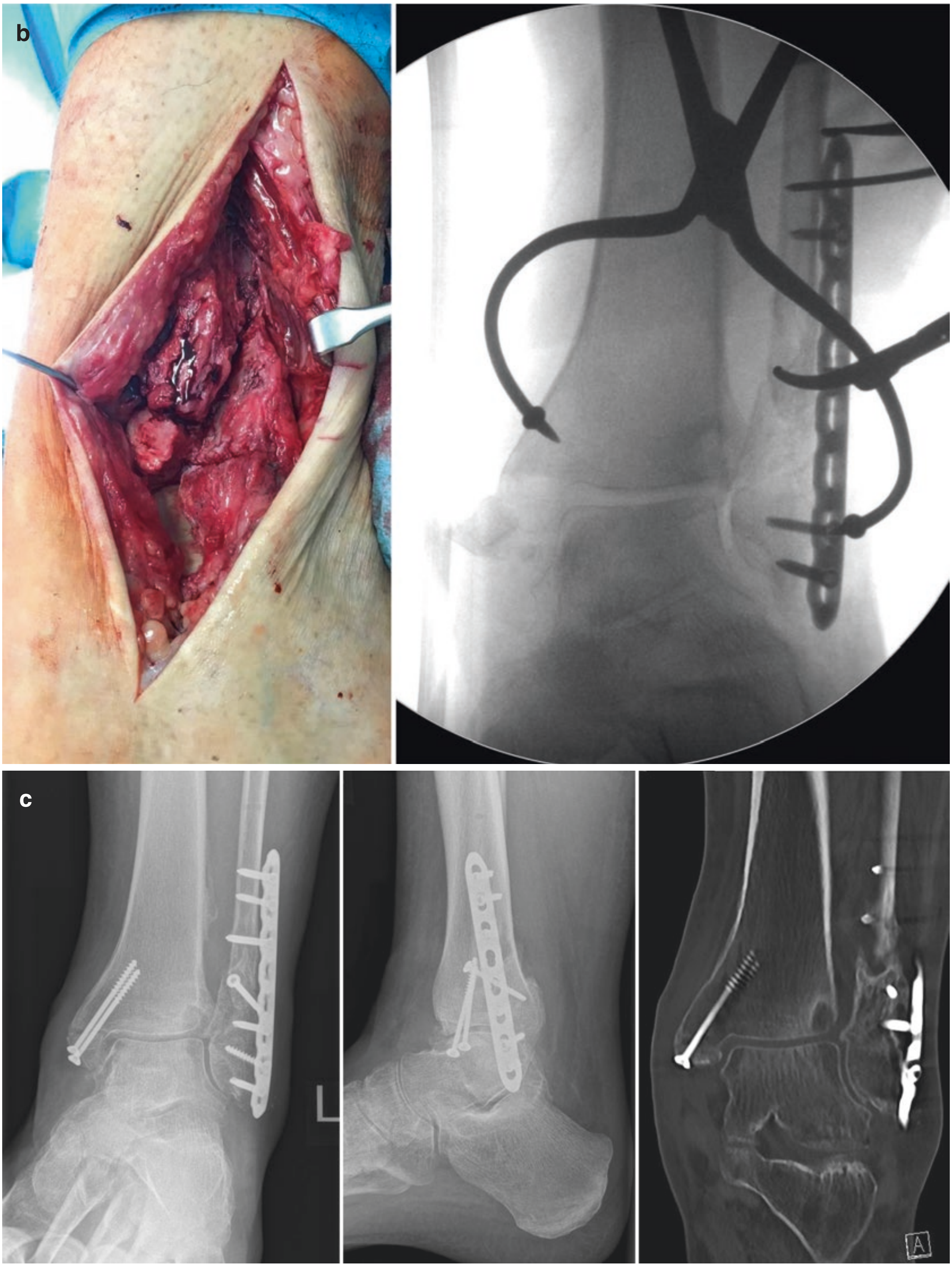

Fig. 18.5 (continued)

patients despite radiographic progression of arthritis in 52% of cases [2]. Recently, Mosca and colleagues also reported ankle joint rebalancing by fibular lengthening was effective in cases with fibular malunion in 33 patients leading to good functional and quality of life scores at 36 months [24]. Although the rates of secondary fusion are low throughout the studies, pre-existing arthritis has been shown to correlate with inferior outcome [1, 2, 28].

4.3 Medial Malleolar Malunion

Isolated malunion of the medial malleolus is uncommon. It is usually part of a more complex deformity with malunion superiorly, laterally, posteriorly or intra-articularly [7, 28]. Less frequently, a supination-adduction mechanism will result to shortening of the medial malleolus due to malunion of the typical vertical shear fracture coupled with the medial displacement of the distal fibular fragment creating the medial talar shift [4]. If there is an additional varus tilt to the talus, it is important to look for accompanying intra-articular impaction of the medial tibia plafond and be ready to correct the intra-articular malunited fragments if necessary. Because in supination-adduction fractures the lateral side gets injured first, there will be either associated lateral ligament instability, an avulsion fracture of the lateral ligament complex, or an inframalleolar fibular fracture malunion as well (Fig. 6). Much rarer, abduction injuries can lead to a transverse avulsion fracture of the medial malleolus and lateral tibial plafond impaction. This can result in avascular necrosis (AVN) of the anterolateral tibial fragment due to injury to the lateral branch of the anterior tibial artery especially in high energy trauma and open fractures [33]. Nonunions of the medial malleolus are rare and are thought to result from technical errors in fixation or non-operative treatment of medial malleolar fractures [34].

For correction, a direct medial approach is used with care taken to protect the greater saphenous vein and saphenous nerve anteriorly, the posterior tibial tendon and posterior tibial neurovascular bundle posteriorly. In the case of malunited supination-adduction injury where the medial malleolus is shortened, a lengthening osteotomy (Fig. 7) is performed via the more vertical former fracture line [4]. In cases of malunited bimalleolar fracture such as pronation-external rotation injury, the medial malleolus is osteotomized along the more oblique former fracture line. The osteotomy is aimed towards the medial edge of the ankle joint at the notch of Harty. In case of additional malunion of the lateral malleolus, it has to be osteotomized also to allow medial malleolar correction.

After the medial malleolar osteotomy is completed, any intra-articular impaction at the medial tibial plafond should be addressed. Any small, loose, or nonviable fragments are removed. Depressed osteochondral fragments can be reduced and congruency of the tibial plafond visually ascertained before fixation with screws. If the fragment is too small, K wires can be used as definitive fixation with the ends cut flush with the edge of the fracture to improve fixation of the osteochondral fragments. Following that, the correct length of the medial malleolus is restored while controlling for congruency of the ankle mortise with direct visualization and image-intensifier. The medial malleolus can be fixed with a medial antiglide plate following a vertical osteotomy and screws or tension-band wiring following a more horizontal osteotomy.

If the distal fibula was simultaneously osteotomized for varus deformity, it can then be shifted laterally and fixed with a lateral plate. Small fragments are alternatively fixed with screws or tension-band wiring. Small avulsed fragments are resected. Lateral ligament reconstruction is performed at this stage, typically with a Brostrøm/Gould repair. This can include reefing of the elongated ligaments, reinsertion into the fibula, and/or talus with suture anchors and augmentation with the inferior peroneal retinaculum [4].

Symptomatic nonunion of the medial malleolus is treated at the same time with debridement of the fibrous pseudarthrosis, drilling of the fragments, and cancellous bone grafting. To fill original screw holes, bone dowels can be

Fig. 6 (**a**) Clinical aspect of a patient with varus malalignment because of medial malleolar malunion following a delayed union of a supination-adduction injury. Note the protruding medial aspect of the heel seen from the front ("peak-a-boo-heel" according to A. Manoli). (**b**) The standing radiographs show shortening and varus malposition of the medial malleolus and widening of the ankle mortise. The lateral malleolus displays a plastic deformity following a low (Weber Type A) fibular fracture but no shortening or medial shift. [Adapted from Ochman S, Rammelt S. Sprunggelenkfrakturen und Korrektur von Fehlheilungen. In: Sabo D, Rammelt S (eds.): Rückfußchirurgie. Berlin, Springer, 2017, S. 236–255, with permission]

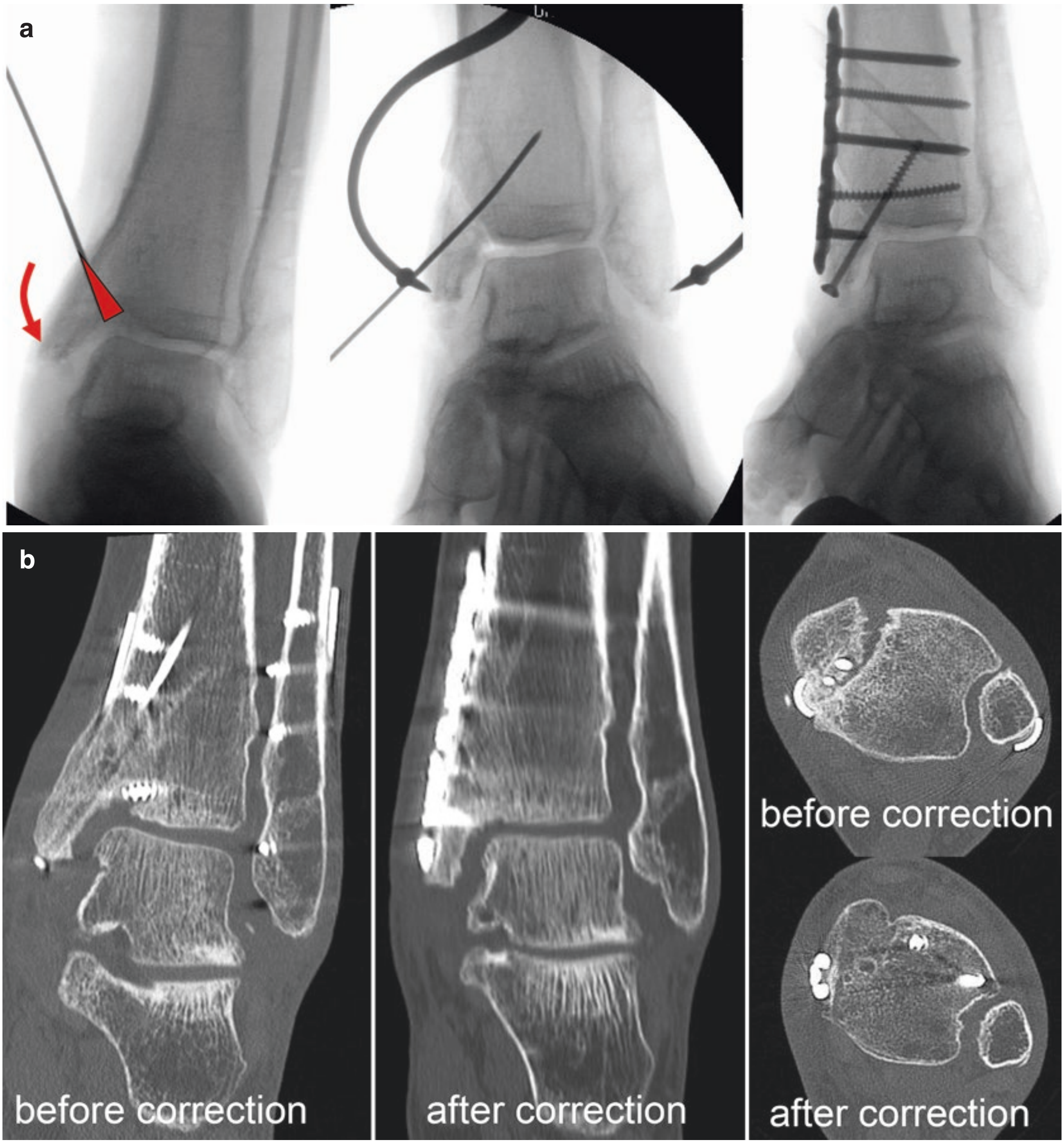

Fig. 7 (**a**) Correction of medial malleolar malunion (same patient as in Fig. 6). A vertical osteotomy is performed together with a wedge resection in order to close the ankle mortise. The medial malleolus is then lengthened, moved laterally, derotated and fixed with a lag screw and medial buttress plate. (**b**) CT scanning at 1 year (prior to implant removal) demonstrates correction of medial malleolar length varus and malrotation in the coronal plane with a stable ankle mortise and correction of hindfoot varus. [Adapted from Ochman S, Rammelt S. *Sprunggelenkfrakturen und Korrektur von Fehlheilungen*. In: Sabo D, Rammelt S (eds.): Rückfußchirurgie. Berlin, Springer, 2017, S. 236–255, with permission]

inserted, press fit, into the former screw holes [4]. Internal fixation can be achieved with a medial plate.

Data on outcome following medial malleolar malunion and nonunion correction are scarce. Sneppen et al. [32] reported a union rate of just 50% after revision surgery for medial malleolar nonunions. Others only anecdotally reported successful revision fixation with bone grafting or excision for small fragments [4, 5, 7]. In the authors' experience, the outcomes of medial malleolar correction are favourable without the need for secondary fusion.

4.4 Posterior Malleolar Malunion

Malunions and nonunions of the posterior malleolus are common as up to 50% of ankle fractures have posterior malleolar involvement that is not always adequately addressed [16, 29, 35, 36]. Malunited posterior malleolar fragments can present as an isolated deformity or in combination with lateral, medial, or intra-articular malunion of the ankle according to the original pathomechanism. Smaller fragments (Bartoníček and Rammelt Types 1 and 2) are most likely caused by ligamentous avulsion in a rotational injury [37]. Two-part and multifragmentary fractures with medial extension and large triangular fractures (Bartoníček and Rammelt Types 3 and 4) usually arise from combination mechanisms of rotational, abduction, and axial compression forces which is associated with pronation injuries [37]. Intercalary fragments and plafond impaction point to an additional axial force resulting in "partial" or "posterior" pilon fractures [16, 38]. Notably, posterior malleolar malunion can be associated with bony syndesmotic instability as it carries the attachment of the posterior inferior tibiofibular ligament (PiTFL). With increasing fragment size, it also affects the integrity of the tibial incisura leading to fibular malposition and syndesmotic incongruity [16, 29]. Irrespective of the size of the fragment, articular incongruity with a step-off ≥2 mm is an independent risk factor for inferior outcomes and development of posttraumatic arthritis [35, 38].

Depending on the individual original pathoanatomy, correction of posterior malleolar malalignment aims at restoring:

1. Articular congruency.
2. Posterior ankle stability and talar containment.
3. The shape of the tibial incisura to enable correct positioning of the distal fibula.
4. Bone-to-bone syndesmotic stability.

Typically, the posterior malleolar fragment malunites in a superiorly displaced position with a posterior articular step-off (Fig. 8). This can be associated with a shortened fibula as illustrated earlier in combination injuries. These deformities can be treated with corrective osteotomies and/or debridement with bone grafting along the former fracture line and fixed with screws or plates [4, 7, 29]. The malunited posterior fragment can be accessed like an acute posterior malleolar fracture via a posterolateral or posteromedial approach. Alternatively, a transfibular approach can be used if a fibular osteotomy is needed for complete correction.

In the authors' preference, the patient is placed prone and a posterolateral approach is utilized. The sural nerve has to be identified and protected in the subcutaneous tissue. Dissection is carried down through the superficial and deep crural fascia in the interval between the peroneal and flexor hallucis longus muscles to the posterior distal tibia surfaces. The posterior ankle joint capsule

Fig. 8 (**a**) Malunion of a large posterior malleolar fragment (Bartoníček & Rammelt Type 4) following a trimalleolar ankle fracture. The medial and lateral malleolus are healed in a physiological position. (**b**) Sagittal CT shows a 2-mm step and MRI reveals bone marrow edema in the distal tibia adjacent to the step-off indicating pathologic pressure distribution at the joint. [Adapted from Ochman S, Rammelt S. *Sprunggelenkfrakturen und Korrektur von Fehlheilungen.* In: Sabo D, Rammelt S (eds.): Rückfußchirurgie. Berlin, Springer, 2017, S. 236–255, with permission]

can be dissected to visualize the joint while the PiTFL must remain intact. Using fluoroscopy, the former fracture line is marked with 1 or 2 K-wires, and an osteotomy is performed with a chisel carefully along this line to the articular step-off (Fig. 9). As mentioned earlier, a transfibular approach can be performed for direct visualization of the posterior lateral joint surface if a fibular osteotomy has to be carried out as part of a more complex correction [7].

Occasionally, a separate posteromedial incision may be necessary for those with medial extension in malunited Bartoníček and Rammelt Type-3 fractures [29].

The posterior malunited fragment is reduced flush to the anterior articular surface of the tibia together with some coronal plane adjustment. This adjustment is typically medial because the posterior tibial fragments follow the fibula via the pull of the PiTFL. Fixation can be performed with interfragmentary screws alone or a dorsal antiglide plating with compression screws through the plate [7, 36, 47]. Once the posterior tibial fragment has been fixed in the correct position, syndesmosis stability will be restored in most cases without the need for additional tibiofibular fixation [17].

While there is a large body of literature dealing with the results of malleolar fractures involving the posterior malleolus, only a few studies report the results of posterior malleolar correction. However, they exclusively report favourable results with pain relief and joint-preservation over several years [7, 9, 29, 36].

4.5 Anterior Malleolar Malunion

Malunions of the anterolateral tibia tubercle (anterior malleolus, Tillaux/Chaput fragment)—like acute fractures—are rarely seen in isolation [39]. Acute anterior malleolar fractures are thought to occur during the first stage of SER injuries, representing avulsions of the anterior inferior tibiofibular ligament (AiTFL) [39, 40]. In pronation injuries, the anterolateral distal tibia fracture is thought to occur in a second stage [40]. An additional abduction mechanism may lead to marginal impaction of the anterolateral tibial plafond [33, 39]. Consequently, anterior malleolar fractures have recently been characterized using CT imaging into 3 types [39];

Type 1—extra-articular avulsion of the AiTFL.
Type 2—fracture involving the joint surface and tibial incisura.
Type 3—fracture with impaction of the anterolateral tibial plafond.

Fig. 9 Correction of a posterior malleolar malunion (same patient as in Fig. 8). The patient is placed prone and a posterolateral approach is employed. The osteotomy is marked with a K-wire and carried out with a chisel under fluoroscopy. The fragment is reduced flush to the anterior part of the tibia and fixed with a posterior antiglide plate

Similar to the posterior malleolus injury, with medial extension, the impaction fracture may involve the whole anterior tibial plafond, resulting in an **anterior pilon** fracture and malunion if not treated adequately [39, 41].

The anterior malleolus shares many analogies with the posterior malleolus with regard to potential consequences in case of malunion and nonunion. Anterior malleolar malunion can lead to bony **syndesmotic instability** due to the attachment of the AiTFL, **malpositioning of the distal fibula** because of malunion of the anterior incisura and **joint incongruity** in the case of residual step-off or marginal plafond impaction [20, 30, 39]. Typically, there is superior and anterior displacement of the plafond fragment that pulls the distal fibula due to the AiTFL and loss of the anterior tibial incisura. The talus shifts anteriorly because of the loss of anterior containment (Fig. 10). A specific late complication is avascular necrosis of the (antero-) lateral tibial plafond [33].

Correction of the anterior malleolar malalignment aims at recreating

1. The articular surface of the anterolarteral tibial plafond.
2. The shape of the incisura.
3. The position of the distal fibula.
4. Bone-to-bone syndesmotic stability
5. Anterior talar containment.

Malunited fractures of the anterolateral distal tibia are typically accessed via a direct anterolateral approach [30, 41–43]. Approaches may vary due to additional procedures, e.g. fibular or supramalleolar osteotomy (Fig. 11). Existing scars from previous surgery are respected. Dissection is carried down to the scarred anterior joint capsule which is resected. This exposes the anterior tibial plafond, the syndesmotic attachments at the anterior tibial and fibular tubercle, the anterior talar dome and lateral compartment

Fig. 10 Obvious incongruity of the ankle mortise following trimalleolar fracture fixation. CT reveals anterior and medial malposition of the anterior distal tibial fragment (anterior malleolar malunion) resulting in fibular malposition due to disintegration of the tibial incisura (fibular notch) and syndesmotic incongruity. In addition, the fibula is shortened. [Adapted from: Rammelt S, Zwipp H. *Korrektur fehlverheilter Fibulafrakturen.* In: Hamel, J, Zwipp H (eds.): Meistertechniken in der operativen Orthopädie und Unfallchirurgie. Sprunggelenk und Rückfuß. Berlin, Springer, 2016, S. 83–92, with permission]

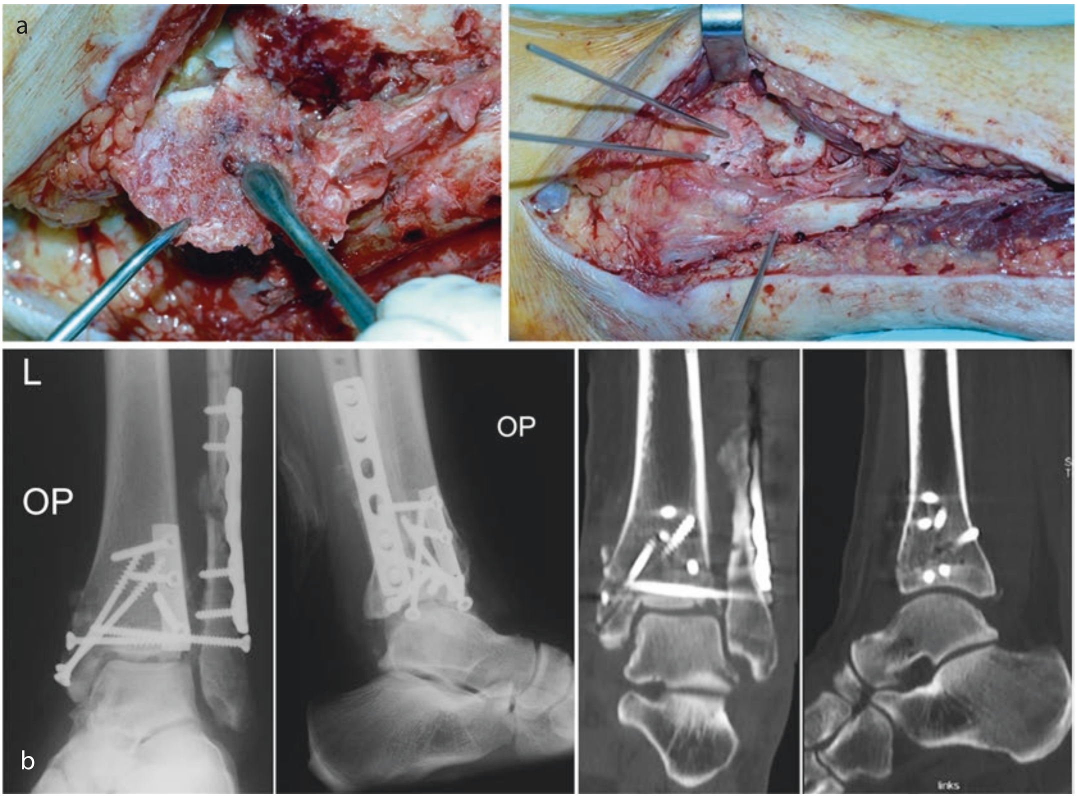

Fig. 11 Early correction of an anterior malleolar malunion (same patient as in Fig. 10). (**a**) Intraoperative images after osteotomy of the anterior malleolar fragment and reduction followed by K-wire fixation. The anterior distal tibia is stabilized with an anterior antiglide plate. A syndesmotic screw is added to enhance syndesmotic healing. The fibula is lengthened and fixed with a locking plate and the distraction site filled with cancellous bone graft. (**b**) Postoperative radiographs and CT scans demonstrate a congruent ankle mortise and joint position. [Adapted from: Rammelt S, Zwipp H. *Korrektur fehlverheilter Fibulafrakturen.* In: Hamel, J, Zwipp H (eds.): Meistertechniken in der operativen Orthopädie und Unfallchirurgie. Sprunggelenk und Rückfuß. Berlin, Springer, 2016, S. 83–92, with permission]

of the ankle joint. The lateral branch of the superficial peroneal nerve and the extensor digitorum longus are gently mobilized medially. The anterior perforating branch of fibular artery consistently penetrates the tibiofibular interosseous membrane at 5 cm above the ankle joint and runs distally across the AiTFL.

The malunited anterior malleolar fragment is mobilized via osteotomy along its former fracture line. In case of nonunion, the fibrous tissue between the fragment and the anterolateral tibia is resected. The fragment is mobilized carefully and left hinging on the AiTFL. In the presence of a plafond impaction (malunited type 3 fracture), a second, incomplete osteotomy is carried out parallel to the joint line and congruity of the plafond is restored under direct vision by mobilizing the articular fragment distally, using the talar dome as a template [41]. In case of AVN, necrotic bone is resected. Bone grafting is performed for resulting subchondral defects, but also after debridement of the fibrous nonunion. Anatomic reduction of the hinged anterior malleolar fragment is then carried out with direct visualization of the articular congruency and held provisionally with K-wire(s). As with acute anterior malleolar fractures, internal fixation may be achieved with an anterolateral distal tibial antiglide plate for malunited type 3 fractures or screws for malunited type 2 fractures. Separate screws may be needed for fragment specific fixation. Malunited syndesmotic avulsions (type 1) are mobilized and reattached to the distal tibia under correct tension with suture anchors [42].

With regards to outcomes, there are only scarce reports on early or late anterior malleolar correction for either isolated Chaput fragment malunion [43], complex correction for failed trimalleolar fracture fixation [42, 44], bony anterior syndesmosis repair [30], or anterior pilon malunions [7, 41], all with good short to mid-term outcomes.

4.6 Supramalleolar Deformities and Malunited Tibial Pilon Fractures

In cases where there are associated supramalleolar deformities, the entire ankle and hindfoot alignment must be assessed properly to look for the primary level of the deformity and any compensatory or additional deformities distally such as talar tilt or anterior shift as well as excessive heel varus or valgus. Furthermore, though coronal plane deformities (varus or valgus) are more frequently encountered, sagittal plane malalignment must also be reviewed and corrected at the same time [4, 45].

Posttraumatic **supramalleolar malunions** mostly result from tibial pilon fractures and may be combined with intra-articular deformities [6, 7, 44, 46]. Partial impaction of the tibial plafond articular surface can occur medially with supination-adduction fractures, laterally with pronation-abduction fractures, or as the result of posterior or anterior malleolar fractures [37, 39, 41]. Supramalleolar malunions can also result from premature closure of the medial physeal plate following (undetected) medial malleolar fractures in childhood [47]. If the joint cartilage is still intact over more than half of the articular surface, a supramalleolar or intra-articular osteotomy can be performed to correct the eccentric loading on the ankle joint [6, 7, 13, 14, 41, 44–49]. The aim is to correct varus, valgus, excessive ante- or recurvatum, and intra-articular malunion of the tibial plafond. The principle applied in this procedure is similar to the high tibial osteotomy which is to transfer the eccentric load away from the eroded cartilage and towards to normal side of the joint. Additionally, one must also consider correction of the ligamentous instability and inframalleolar compensatory deformities (hindfoot and midfoot) due to chronic hindfoot malalignment [4, 14]. Supramalleolar tibial osteotomy has also been added to fibular lengthening osteotomy for malunited pronation-external rotation fractures in order to offload the particularly vulnerable lateral tibial plafond following malleolar malunion [49].

The supramalleolar osteotomy is performed using an opening or closing wedge technique depending on the clinical presentation. The surgeon must take into account the quality of the soft tissue coverage, the presence of bone loss, any shortening of distal tibia, and available technical knowledge. Opening wedge supramalleolar osteotomy is regularly preferred in cases of posttraumatic shortening of the distal tibia due to impaction or bone loss provided the medial soft tissue envelope is not compromised (Fig. 12). A fibular osteotomy is usually added in cases of concomitant fibular deformity or if the distal medial opening wedge is >10° [13]. A disadvantage of opening wedge osteotomy includes the need for bone graft with longer time to healing and the risk of nonunion when compared to closing wedge osteotomy [14]. Alternative techniques including oblique sliding and dome osteotomies have been shown to be able to correct angular deformity and length without the need for bone grafting [50]. A combination of supramalleolar osteotomy and intra-articular osteotomy via medial malleolar osteotomy can also be performed for malunited medial malleolar fractures with impaction [44].

If **inframalleolar deformities** are noted such as talar tilt in a varus ankle deformity, an oblique tibial osteotomy can be performed to address both the supramalleolar varus deformity and reduce (close) the ankle mortise to address ankle instability [51]. Often, excessive heel varus is present and will benefit from a combination of valgus (closing wedge or Dwyer) osteotomy, lateral shift of the calcaneus, and reefing of the

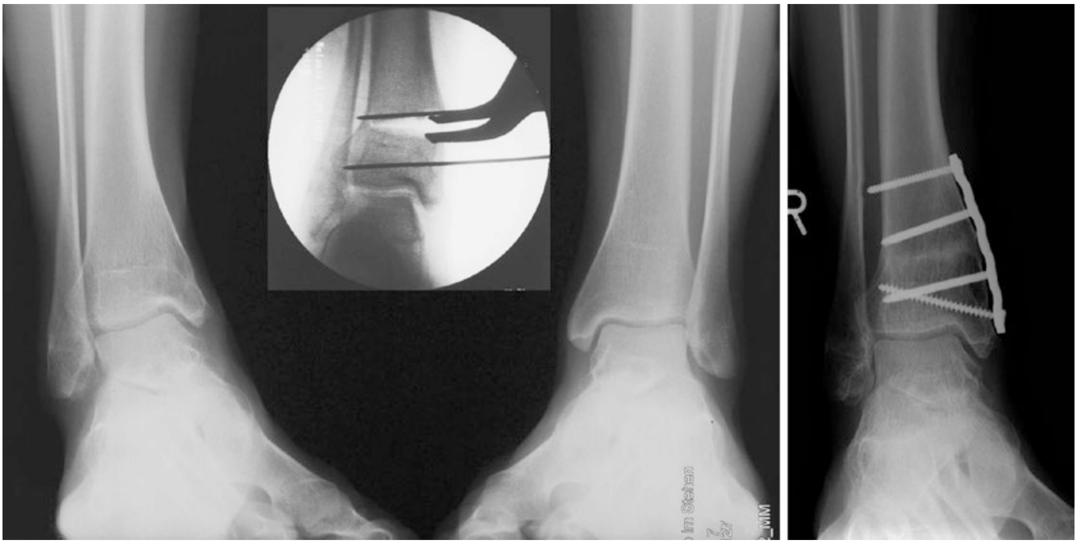

Fig. 12 Opening wedge supramalleolar osteotomy in a 23-year old patient for varus deformity resulting from a medial malleolar fracture 10 years ago with subsequent premature closure of the physeal growth plate. The patient was increasingly symptomatic since 3 years

chronically avulsed or elongated lateral ligaments [4]. In case of erosion or impaction of the medial tibial plafond resulting in an intra-articular deformity, the osteotomy line is directed more obliquely at the apex of intra-articular deformity to correct the deformity right at the center of rotation and angulation (CORA) resulting in a plafond-plasty [48]. Conversely, lateral impaction of the tibial plafond or avascular necrosis of the anterolateral tibial metaphysis resulting from abduction injuries may warrant an intra-articular osteotomy with lateral bone grafting [4, 41].

The surgical approach is typically dictated by pre-existing scars and implants, the apex of the deformity, and the direction of correction. Distal tibia osteotomy is performed via an (antero-) medial approach while osteotomies of the distal fibula warrant a lateral approach. The osteotomy should ideally be performed at the level of the CORA to gain maximal correction. However, in malunited ankle or pilon fractures, the CORA often lies very close to or at the ankle joint. Therefore, if a joint preserving osteotomy is planned, the osteotomy must be performed more proximally [14, 46]. The exact site and angle of the osteotomy should be planned preoperatively and marked intraoperatively with K wires while the amount of correction is confirmed with intraoperative fluoroscopy. For stability reasons, the osteotomy line should be targeted at the proximal 1/3 of the intrasyndesmosis plane. Nha et al. stated that osteotomy performed at the suprasyndesmosis plane has a higher risk of lateral hinge fracture while osteotomy performed at the proximal 1/3 of the intrasyndemosis plane can tolerate an opening wedge of up to 20° without lateral hinge fracture or with stable lateral cortical fracture without the need for fibular osteotomy due the ligamentous support of the syndemosis [52]. In addition, overcorrection of the deformity by 3° to 5° in the coronal plane is recommended by most authors to achieve a lateral distal tibial angle between 93° and 95° [13, 14].

Once the osteotomy line is marked with a K-wire and confirmed with fluoroscopy, an oscillating saw can be used under continuous water irrigation to reduce thermal damage. One must ensure that the saw blade is perpendicular to the tibia and parallel to the K wire marker. Subsequently, the osteotomy is stopped a few millimetres short of the opposite cortex to prevent hinge fracture and secondary displacement of the distal fragment during deformity correction. An osteotome can be inserted into the osteotomy line initially to spread it open just enough to insert a lamina spreader for further controlled opening of the wedge. Once the amount of correction is acceptable, bone graft is inserted into the opening wedge and fixation is performed typically with a medial locking plate. In case of poor bone quality, a medial or posterior blade plate may provide superior stability (Fig. 13). Care is taken to correct additional sagittal plane deformities (inclination/declination of the distal tibia) [4, 45].

Simple **intra-articular malunions** can be corrected with intra-articular osteotomies along the former fracture line in exceptional cases with still intact cartilage in young, active, and compliant patients with sufficient bone stock [6, 7]. For long-standing deformities, an oblique supramalleolar osteotomy can be guided to the apex of the deformity ("plafond-plasty") [41, 48].

If a fibular osteotomy is needed, an oblique osteotomy increases the bony surface contact area. The fibula can be fixed with a one third tubular plate. In cases where there is concomitant medial malleolar and supramalleolar deformities, a double osteotomy may be needed to first correct the supramalleolar varus deformity followed by medial malleolar osteotomy for lengthening and narrowing of the ankle mortise [6, 44]. A combination of medial locking plate and screws can be used for fixation of this double osteotomy.

Favorable results have been reported after supramalleolar, intra-articular osteotomy (plafond plasty), and medial malleolar osteotomies to correct eccentric loading [7, 13, 14, 22, 45–51]. In fact, a recent study on second-look arthroscopic evaluation of 29 ankles after supramalleolar osteotomy without marrow stimulation for medial ankle osteoarthritis showed that 26 (89.7%) ankles showed cartilage regeneration at the medial compartment of the ankle joint as a result of load redistribution and none had deterioration of cartilage status at 2.9 years postoperatively [53].

In addition, there are a few published series and reports on corrective intra-articular osteotomy for malunited pilon fractures reporting good outcomes at 2–5 years [6, 7, 41, 54]. Patients have to be counselled that posttraumatic arthritis may progress despite correction, but only a small percentage (14%) will need a secondary fusion [6]. Frequently, medial plates will have to be removed because they are felt through the skin and result in irritation in tight shoewear.

Fig. 13 Closing wedge supramalleolar osteotomy in a 55-year old, poorly compliant patient with varus malalignment and inclination of the distal tibia following trimalleolar fracture fixation with impaction of the plafond. A posterior blade plate is used to achieve correction and stable fixation

5 Late Syndesmosis Injuries of the Ankle

The management of syndesmotic injuries is a key to success in the treatment of malleolar fractures as chronic instability can lead to posttraumatic ankle arthritis [19, 20, 30]. It was reported that 20–45% of all operatively treated ankle fractures involved syndesmosis injuries [55]. In addition, up to 52% of syndesmotic injuries were found to be malreduced after closed reduction and 16% even after open reduction and fixation with post-operative CT scanning [10, 12, 55].

Late or chronic syndesmotic injury is a broad umbrella term encompassing a spectrum of symptoms and functional deficits of variable severity and duration. The 2016 ESSKA-AFAS consensus on syndesmotic injuries have classified syndesmotic injuries based on duration since trauma as **acute** being **<6 weeks**, subacute as between 6 weeks and 6 months, and **chronic** being **>6 months** [56]. Irrespective of the time from injury, syndesmotic instability can be classified as **frank or latent diastasis**, the latter becoming evident on stress examination [57]. In this section, evaluation and reconstructive options for subacute and chronic ligamentous syndesmosis injuries will be discussed as bony syndesmosis instability secondary to malleolar malunions has been addressed earlier. It goes without saying that any **concomitant bony deformities** have to be addressed simultaneously in every case of chronic syndesmotic instability in order to achieve a sufficient correction—and vice-versa [4, 30].

5.1 Specific Preoperative Evaluation and Planning

The presenting complaint can be non-specific ankle pain upon weight-bearing with persistent swelling and limited range of motion following a high ankle sprain, typically an eversion injury [30]. It may also be associated with subjective feeling of instability (“giving way”) on uneven grounds masquerading as lateral ligament complex instability. Clinical examination includes palpation of the anterolateral ankle (anterior syndesmosis) where tenderness may be aggravated with dorsiflexion of the foot. Forced external rotation of the foot against a fixed lower leg may also reproduce the pain as the syndesmosis is stressed [19]. Calf or syndesmosis squeeze test can be performed as well although it may not be that specific in chronic injuries. Han et al. reported that palpation of the anterior syndesmosis produced a dull tenderness in 18 out of 20 patients with chronic syndesmotic injuries, only 3 out of 20 had a positive external rotation test and 2 out of 20 had positive calf squeeze test reflecting a 90%, 15%, and 10% specificity respectively [58]. Other recommended tests include a ‘fibular translation’ test that is performed by drawing the fibula forward and backward while the tibia is fixed with the contralateral hand. A manual ‘Cotton’ test may be performed by cupping the heel and applying medial and lateral forces to the talus with the ankle in neutral position stabilized by the contralateral hand [56]. Keep in mind that symptoms from posttraumatic ankle arthritis may overlap with those of syndesmotic instability.

Weight-bearing radiographs of both ankles in lateral and mortise views are indispensable for assessing any ankle malalignment including chronic syndesmotic instability [30]. The most relevant radiographic parameter for syndesmotic integrity is the “ligne claire” (tibiofibular clear space [TCS]) as originally described by Chaput (Figs. 3 and 14). It is considered the most reliable indicator as it is not significantly affected by tibial rotation [19, 56]. Other radiographic measures include the tibiofibular overlap (TFO) and the medial clear space (MCS). On weight-bearing mortise views, syndesmosis integrity is maintained if the TCS is less than 6 mm and TFO is greater than 1 mm although this reference is larger in males [10, 30] and may be completely absent as normal variant [59]. Furthermore, the TCS measured in mortise view seems to increase with age [56]. Because of the considerable anatomic variability, bilateral radiographs are essential [59]. A TCS and MCS widening of 2 mm or more compared to the contralateral unaffected ankle is considered to be pathologic [30, 60]. In addition, sagittal instability of the syndesmosis will regularly be present when the fibula migrates posteriorly reinforcing the importance of analysing the lateral view of the ankle radiographs [30]. Schreiber et al. [61] described use of the posterior tibiofibular distance, while Grenier et al. [62] proposed the anteroposterior tibiofibular (APTF) ratio to ensure sagittal instability is not missed.

CT scanning of both ankles is the gold standard for assessment of syndesmosis integrity. The standard view would be the coronal cut located at 10 mm proximal to the tibial plafond (Fig. 14) although more inferior levels closer to

Fig. 14 (**a**) Standing radiographs and (**b**) CT imaging of chronic syndesmotic instability as evidenced by tibiofibular diastasis with marked widening of the MCS. In addition, there is fibular shortening and valgus following a pronation-external rotation injury

the tibial plafond have been reported [10, 30, 59]. As with plain radiographs, there is a high interindividual but low intraindividual variability of the radiographic measurements [59, 62]. Any side-to-side difference in fibular translation or syndesmosis diastasis more than 2 mm is considered pathological [30]. In addition, weight-bearing CT scans have recently gotten a role in the assessment of subtle syndesmosis injuries combining the benefits of physiologic loading and three-dimensional imaging. However, it is still unclear if it is superior to conventional CT scanning in the diagnosis of acute or chronic instability [63].

Ankle arthroscopy, as an invasive procedure, only allows for evaluation of the anterior portion of syndesmosis with the interosseous and posterior part less accessible [56, 60]. Granted, it allows assessment of associated injuries such as cartilage or lateral ligamentous injuries.

5.2 Treatment of Subacute Syndesmosis Injury

This group of patients presents from 6 weeks to 6 months post injury with a variable temporal progression of symptoms. In patients with no diastasis, symptoms are generally due to the impingement of hypertrophic synovium and scar tissue within the tibiofibular space and adjacent anterolateral part of the ankle joint. Treatment consists of **arthroscopic debridement** of the syndesmotic scars with excellent outcomes including improved range of motion and relief of symptoms [30, 58, 64]. Usually, there is no need for additional "prophylactic" syndesmotic stabilization with screws or suture button device as they have been reported to not produce improved outcomes [58, 65]. Syndesmotic stabilization is only needed if it is clinically unstable after debridement upon arthroscopic or fluoroscopic stress examination.

In another group of patients with subacute syndesmosis injury and instability, the patients display diastasis of the ankle mortise in standing radiographs, typically after returning to full weight-bearing with or without removal of the syndesmotic screw or flexible implant. The ankle joint is eccentrically loaded thus having a higher predisposition to arthritis [9, 60]. In this scenario, the aim is to debride any interposed scar tissues and **repair the AiTFL** provided that adequate remnant ligaments are present. It has been reported that anatomical reconstruction or repair of the anterior syndesmosis may be sufficient to produce fibrotic healing with good outcomes [66]. Favourable results have been achieved when debridement or AiTFL repair was followed by **syndesmotic stabilization** with a combination of position screw and/or suture button [30, 66]. If there is dystopic ligament healing or elongation, medial and proximal advancement of a bone block from the anterior tibia (Chaput) tubercle to tighten the stretched out AiTFL coupled with a position screw placement, produced good outcomes as well [67]. Likewise, a malunion or nonunion of a posterior malleolar (PiTFL) avulsion is debrided, advanced, and fixed with a screw followed by reduction of the distal fibula into the incisura and syndesmotic stabilization (Fig. 15).

If the medial clear space remains displaced after syndesmotic reduction, the medial gutter and **deltoid ligament** must be explored and intervening scar tissues removed. Occasionally, a torn and unstable deltoid ligament may necessitate repair or reconstruction especially in the presence of valgus tilt of the talus [30].

If there is insufficient soft tissue or remnant syndesmosis tissue left after debridement for repair or approximation, soft tissue reconstruction of the syndesmosis via **ligamentoplasty** is a viable option [68]. The authors prefer to use a split peroneus longus tendon graft for a near-anatomic reconstruction of the AiTFL, interosseous ligament and PiTFL to recreate the dynamic three-point fixation of the distal fibula. Using a split peroneus longus tendon has minimal functional deficit after transfer as it has minimal contribution to foot eversion and does not result in lateral ankle instability, in particular with half of the tendon remaining in place. The technique involves a direct lateral approach to the distal fibula. The peroneus longus tendon is exposed behind the fibula and separated from the peroneal brevis. Using the same approach, the syndesmosis is exposed and all scar tissues debrided. The

Fig. 15 (**a**) Subacute syndesmotic instability with diastasis following lateral malleolar fixation but neglect of PiTFL avulsion resulting in nonunion of the posterior malleolar fragment and rotational instability of the distal fibula without fibular shortening. (**b**) The posterior malleolar fragment is debrided, reduced, and fixed with an antiglide plate via a posterolateral approach recreating the fibular notch and facilitating fibular reduction. A flexible implant (suture button) is employed to enhance syndesmotic fixation

peroneus longus tendon is divided into equal parts from the tip of the fibula upwards to a 15–18 cm length. The anterior split portion of the tendon is guided through three bone tunnels in the distal tibia and fibula, mimicking the anatomic trajectory of the syndesmotic complex (Fig. 16). The fibula is reduced into the tibial incisura with a large pointed reduction forceps, and anatomic reduction is checked with mortise and lateral radiographs. If the medial clear space

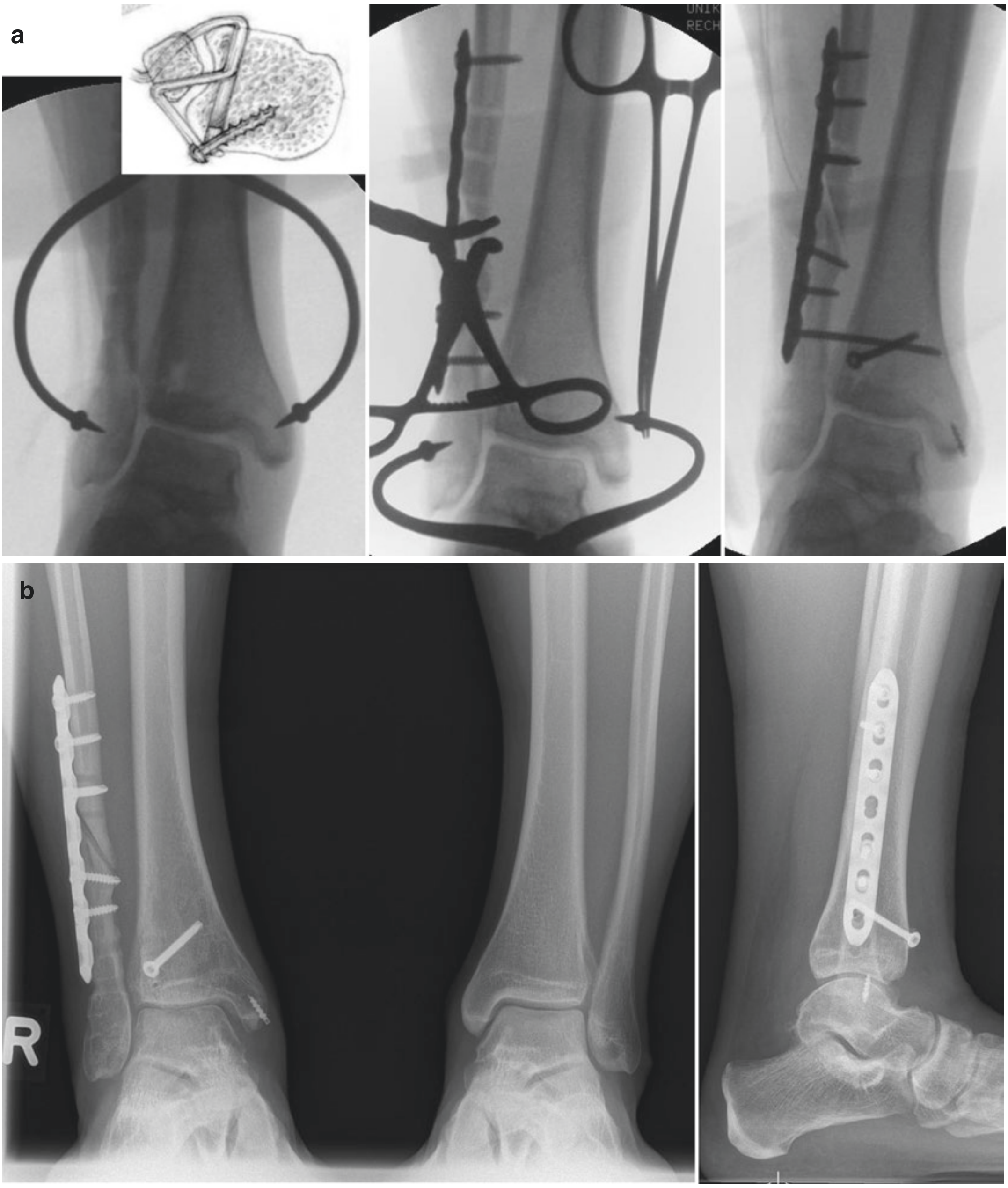

Fig. 16 Peroneus longus ligamentoplasty (same patient as in Fig. 14). (**a**) Following debridement of the syndesmosis and medial gutter, a split peroneus longus tendon is used to restore the three-point-suspension of the syndesmosis [68]. Despite syndesmotic stabilization, there is still talar shift and tilt doe to fibular shortening and valgus which is corrected by an oblique distal fibular osteotomy. The chronically unstable deltoid ligament is reefed to the medial malleolus with a suture anchor. (**b**) At 1 year, weight-bearing radiographs demonstrate a stable ankle mortise. The syndesmotic screw was removed at 8 weeks, alternatively, it may be left in place

is still wide, scar and pannus tissue is debrided via a small anteromedial approach. Once reduction and fixation is satisfactory, a syndesmotic screw is inserted to protect the ligamentoplasty for at least 8 weeks postoperatively. The free end of the tendon graft is secured under correct tension at the anterolateral tibial tubercle with a 3.5 mm cancellous screw and washer. Published results from the first 16 patients followed for an average of 18 months were encouraging with 93.8% reporting significant pain relief and a mean Karlsson score of 88 [68]. Since then, the authors have treated more than 150 patients using similar method with mostly good outcomes. Failures were seen in the presence of symptomatic arthritis or bony defects at the distal tibia or fibula at the time of revision surgery [30].

There are several other types of tenodeses or ligamentoplasties available for reconstruction using multiple types of grafts. Connors and colleagues used a split semitendinosus allograft to reconstruct the AiTFL and interosseous ligament via a tiered double level bone tunnel followed by stabilization with 2 syndesmotic screws which were removed at 6 months [69]. Morris et al. reconstructed the AiTFL and interosseous ligament with a free hamstring autograft [70]. Other options of grafts include peroneus brevis, free gracilis, and plantaris tendons, fascia lata, and free hamstrings tendon allograft [30]. More recently, fixation devices like internal bracing have been employed for replacement or reinforcement of the AiTFL and interosseous portion of the syndesmosis [71]. All of these soft tissue reconstructions of the syndesmosis have been reported to produce good outcomes and pain relief in the short to medium term.

5.3 Treatment of Chronic Syndesmosis Injury

Chronic injuries of the syndesmosis (beyond 6 months) may present with frank or latent diastasis and posttraumatic arthritic changes depending on the time from injury and amount of instability. The syndesmotic space is filled with scar tissue and pannus at the time of presentation. Thorough debridement typically leaves few remnants for direct syndesmotic repair leaving either ligamentoplasty or tibiofibular fusion as treatment options in the absence of advanced posttraumatic ankle arthritis.

With good bone stock at the distal tibia and fibula, many authors advocate dynamic soft tissue reconstruction of the syndesmosis via **ligamentoplasty** as described above [30, 56, 68–70]. This will allow some residual tibiofibular motion and thus a near physiologic action of the ankle joint. Tibiofibular fusion remains a salvage option in cases of failed ligamentoplasty or when soft tissue reconstruction is not feasible due to poor bone quality, avascular necrosis of the lateral tibial plafond or severe scarring of the peroneal tendons.

Tibiofibular fusion with bone grafting for chronic syndesmotic instability has been described by several authors [30, 72]. Following debridement of scars and debris in the syndesmotic region, necrectomy is performed in case of AVN of the anterolateral distal tibia [30, 33]. Syndesmotic fusion is achieved with interposition of a corticocancellous bone block and permanent screw fixation. In case of poor bone stock in the distal fibula, screws may be augmented by a small plate. Only a few small series are reported in the literature and are limited to short-term results. Olson and colleagues, in the largest series of ten patients, reported favourable outcomes of tibiofibular arthrodesis at a follow-up of 2 years [72]. There were three reoperations but no secondary ankle arthrodesis was necessary. Although elimination of the three-dimensional fibular motion also affects tibiotalar motion resulting in unphysiological stiffness, secondary ankle fusion has not been reported in the short-term yet, and long-term results of tibiofibular fusion are still pending. Furthermore, even complete posttraumatic tibiofibular synostosis, although associated with limited plantar- and dorsiflexion at the ankle, does not seem to lead to relevant symptoms or inferior results in the affected patients [73]. It appears therefore that tibiofibular synostosis is relevant only with concomitant malposition of the distal fibula [30].

In the presence of advanced ankle arthritis, joint preserving procedures will ultimately fail. Unfortunately, chronic diastasis and instability of the syndesmosis rapidly progresses to ankle arthritis due to significant reduction in contact area and abnormal loading forces in the ankle joint as outlined above. In a study of 735 tibial plafond fractures, it was reported that the 95% rate of posttraumatic ankle arthritis was significantly associated with failure to diagnose syndesmosis injuries and syndesmotic avulsions at the distal tibia and fibula [74]. Primary cartilage damage at the time of injury coupled with inflammatory cytokines further add to the risk of late posttraumatic ankle arthritis and secondary damage to the cartilage surfaces from eccentric loading [75]. In these scenarios, corrective ankle fusion or total ankle replacement with syndesmotic stabilization is the treatment of choice [4, 25, 30]. These treatment options are dealt with in separate chapters of this book.

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